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MAPPING POTENTIAL OF THE IRS-1C PAN SATELLITE IMAGERY

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ABSTRACT

The current and upcoming high resolution satellite imagery is expected to have a significant impact on the topographic mapping applications of primary data acquisition and especially on the updating of databases. The Centre for Topographic Information (CTI), Geomatics Canada has initiated an investigation to evaluate the use of space imagery in the national topographic program from technical, systems and economic points of view. For this purpose a scene and the three CCD scenes from the PAN camera of the Indian Remote Sensing satellite IRS-1C were acquired covering the east of Ottawa region. The initial tests conducted aimed to examine the geometric and radiometric characteristics of the imagery, the detectability and identification of topographic features for data collection and database updating, as well as the suitability of the existing system and the determination of additional requirements. The performance of existing line scanner sensor modelling was tested on the entire IRS-1C scene, on a sub-scene consisting of segments from the three image arrays and on an array sub-scene. Orthoimages were produced from contour generated DEM and geometrically tested. Extraction and classification of topographic features were evaluated from the orthoimagery in a monoscopic mode. For 1:50000 mapping, initial results showed that the imagery can meet the accuracy requirements and when contextual information is available has the potential to support the updating of certain features in new suburban developments and in non urban areas,.

1 INTRODUCTION

The Indian Remote Sensing satellite IRS-1C was launched in December 1995 and carries three sensors. One of them is the PAN camera, a panchromatic sensor with 5.8m spatial resolution and 6-bit (64 grey levels) radiometric resolution. It consists of three CCD linear arrays with 4096 pixels each and covers a swath of about 70km (3x23.3km or approximate 12000 pixels). The dimension of each pixel is 7 micrometers. The three sensors overlap but are neither parallel nor aligned (Srivastava and Alurkar, 1997; Jacobsen, 1998). The configuration of the three CCD sensors on the image plane is illustrated in Fig. 1. The overlap between CCD1 and CCD 2 is 243 pixels and between CCD 2 and CCD 3 is 152 pixels.

The nominal focal length of the PAN camera is 982mm. The IRS-1C satellite is on sun synchronous orbit with an inclination of 98.69 degrees, an attitude of 817km, repetivity of 24 days, local time of imaging at about 10:30am and revisit of 5 days (Shivakumar et al., 1996). The latter as well as stereoscopic across track coverage are accomplished by a rotation of the entire PAN camera up to +/-26 degrees. When marketed, the IRS-1C is resampled to 5m and the three array images are mosaicked to form a scene that covers an area of 70kmx70km. As well the radiometric resolution is scaled to 8-bit quantization levels (256 grey levels). The individual image arrays (left, middle and right) can be obtained as well. Because of its high spatial resolution, the IRS-1C PAN imagery is of significant interest for topographic mapping applications such as primary data collection and database revision and updating.

The Centre for Topographic Information (CTI) has utilized digital orthoimages from aerial photography (Armenakis et al., 1995) and SPOT panchromatic imagery (Savopol, 1994) for updating of the National Topographic Database (NTDB) in a monoscopic mode. Because of cost and spatial resolution, CTI acquired an IRS-1C PAN scene to use in a similar mode and evaluate its geometric and radiometric properties. For this investigation the 287/037 scene, taken on November 25, 1996, and its three individual sub-scenes were acquired. The scene covers the east of Ottawa area. The scene is of nadir view (1.96 degrees). Although this scene was not ideal because of the low sun angle of 23.3 degrees, this scene was selected as being free of clouds and snow coverage at the time of image selection. The evaluation of the existing systems in CTI in using the IRS-1C imagery and determination of additional requirements, if any, are included within the scope of this investigation.

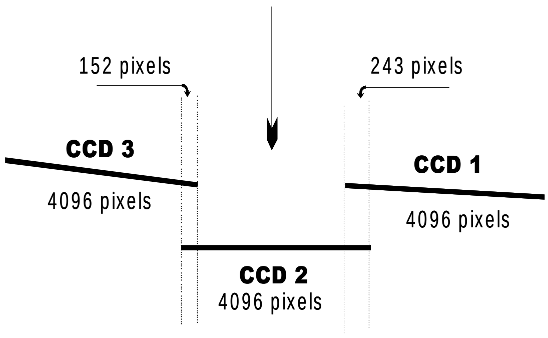

Figure 1: IRS-1C PAN camera configuration (not to scale).

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2 SENSOR GEOMETRIC MODELLING

The handling of the IRS-1C imagery can be done in three ways:

a) Processing measurements from the entire image under the assumption of having been collected by one sensor by re-aligning and re-scaling CCD 1 and CCD 3 images with the CCD 2 image. Then the current available modelling for pushbroom sensor systems can be applied. The ground control points will be located in the perimeter and centre of the image as required.

b) Processing measurements from each sensor array individually with common control points along the overlapping areas among the three image strips, with additional control points distributed as required (in the perimeter and centre of each image array).

c) Processing measurements from all three image arrays simultaneously using tie/control points along the overlapping areas among the three image strips with additional ground control points distributed as required.

Presently the determination of the exterior orientation has been tested for case (a) for both the entire scene and for a sub-scene comprised of parts from all the three arrays as well as for a sub-scene of the central image array (part of case (b)). The commercial system PCI was used for the image measurements and the satellite geometric modelling (exterior orientation).

The IRS-1C image was imported in the EOSAT Fast Format without a Trailer file. Since the Trailer file contains ephemeris information about the orbital parameters of the satellite, the orientation of the scene was based only on the use of ground control points and the PCI's unified geometric modelling for line scanners (pushbroom) type images (Toutin and Carbonneau, 1989; Toutin, 1995).

2.1 Entire scene

In total 32 control points were used distributed across the entire scene. The ground coordinates of the control points had been computed from the aerotriangulation of 1:50000 scale aerial photography from CTI's Aerial Survey Database (ASDB). All points were natural features and most of them were located at road intersections. Their planimetric accuracy is in the order of 1.5-2m, while their vertical accuracy is in the order of 2-2.5m. Aerial photographs and 1:50000 topographic maps supported the identification of the control points on the IRS-1C image. The elevations of the control points were ranged from 55m to 146m. This elevation difference is not significant as it can cause an error of about 1 pixel at the edge of the scene.

Two tests were conducted. In the first, 19 points were used as control points and 13 as check points. In the second, 8 points were used as control points and 24 as check points to represent a more realistic operational situation. Table 1 summarizes the results obtained.

	RMS Rx (pixel)	RMS Ry (pixel)
Control pnts (19)	0.36	0.43
Check pnts (13)	0.55	0.40
Control pnts (8)	0.43	0.46
Check pnts (24)	0.50	0.47

Table 1: RMS of residuals, full scene geometric modelling.

As there was no significant difference between the two solutions, the modelling parameters of the solution with fewer control points were used afterward for the orthoimage generation.

2.2 Subset of the entire scene

A subset of the entire IRS-1C scene was extracted covering the area of one 1:50000 NTS topographic map (apprx. 39kmx28km). The sub-scene was composed from image segments from all three image arrays.

The satellite modelling was performed and evaluated based on 11 control and 19 check points, which were similarly collected as in Section 2.1. The control point distribution with respect to the areas covered by the three CCDs is: 1 in the left array, 7 in the middle and 3 in the right. Respectively, for the check points the distribution was: 1, 12 and 6. Table 2 summarizes the results obtained.

	RMS Rx (pixel)	RMS Ry (pixel)
Control pnts (11)	0.36	0.45
Check pnts (13)	0.58	0.62

Table 2: RMS of residuals, sub-scene geometric modelling.

2.3 Sub-scene of the middle array scene

A sub-scene of the middle CCD array covering area within the same as above 1:50000 NTS map was also considered in order to detect any effects from all the CCDs on the geometric characteristics of the scene. For the orientation of the sensor and its evaluation 10 control and 11 check points were used. Table 3 summarizes the results obtained.

	RMS Rx (pixel)	RMS Ry (pixel)
Control pnts (10)	0.27	0.24
Check pnts (11)	0.40	0.42

Table 3: RMS of residuals, middle CCD sub-scene geometric modelling.

3 ORTHOIMAGE GENERATION

Based on the sensor modelling parameters derived through the process of geometric modelling, three orthoimages were generated covering the area of the 1:50000 NTS map. The first used the parameters derived from the entire scene, the second used the parameters derived from the subset of the entire scene and the third used the parameters derived from the sub-scene of the middle CCD array. The DEM required was derived at 50mx50m spacing from the 10m digital contour lines of the topographic map. The output ground pixel size was set to 5m and the resampling was performed using cubic convolution. It should be noted here that the images have undergone through a second resampling, the first performed during the scene acquisition from 5.8m to 5m. The evaluation of the planimetric accuracy of the orthoimages was performed in three ways.

a) Superimposition of the control and check points on the orthoimage and comparison of their actual ground coordinates with those measured from the orthoimage. The location of the superimposed check points was within 0.5 pixel.

b) Superimposition of vector data from the NTDB. The majority of the superimposed vectors match with their corresponding image features within 1 pixel. It should be noted that certain vector data have been created by scanning of cartographic map layers.

c) Creation of an RGB type image from the three orthoimages covering the same area. If no colour is visible then this is an indication that the orthoimages match. If any of the individual RGB colours is visible, this is an indication of mismatch. In our case we observed a random mismatch at various features of about 1 pixel.

4 EXTRACTION OF TOPOGRAPHIC FEATURES

Both spatial and radiometric resolutions as well as the season, the sun angle and the atmospheric conditions affect the feature identification and extraction from the imagery. For recognition/detection of features, using monoscopic observations the observer's eyes cannot resolve better than 5-10lp/mm, which is equivalent to 0.1-0.05mm. At the 1:50000 scale this means that the image ground pixel size should be between 2.5 and 5m to support effectively the extraction of the topographic base contents. Of course the detection and identification of features depend as well on the type of the feature, its size and shape, the contrast between the feature and its surroundings and its relationship with other known features.

The spatial resolution of the IRS-1C PAN imagery is at the upper limit of the range, while the 6-bit dynamic range will result in a lower contrast. The scaled grey levels of the image ranged from about 70 to 255 (185 values) for both the entire scene and the sub-scenes. To improve the image a 3x3 edge sharpening filter and a square root type contrast stretch were applied, both available on the PCI system. This latter enhancement is particularly effective with images whose histogram displays right skewness. This contrast enhancement stretches the dynamic range of the low end of the image while compresses its high end, thus brightening the image. An additional factor in this test was the low sun angle resulting in long shadows, which may cause some problems with feature identification.

Initial evaluation on the extraction and classification of topographic features performed by McBean, 1998 and the authors led to the following observations:

1- Road network, urban and suburban areas. Roads can be collected easily in new subdivisions and developments, while there is difficulty in core and old urban areas due to the small width of the streets, the shadows and the foliage of trees except for the wide roads.

2- Road network, rural areas. Highways can be easily extracted as well roads, which are not neighboring forest and vegetation.

3- Railways. Can be easily extracted but contextual information is required to identify it. Number of tracks was not visible.

4- Buildings. It was found that it was difficult to identify buildings and more difficult to extract the shape of the building in both urban and rural areas, except for large complexes.

5- Hydrology: Rivers and lakes can be extracted and identified. Not very effective for creeks and steams especially when they flow through vegetation covered areas.

6- Vegetation. The vegetation theme can be identified and its boundaries can be delineated. The type of vegetation can not be determined. Clearcuts are also easy to extract.

7- Built-up areas and various patterns (i.e., agricultural, golf courses) can be identified as well.

With the existing vector data superimposed the feature extraction is much easier due to the additional contextual information. Thus, the imagery has the potential to support the updating the 1:50000 national topographic database, particularly in new urban and sub-urban developments and in rural areas when contextual information is used.

5 CONCLUSIONS

Initial results have demonstrated that the entire scene produced by properly re-aligned, re-scaled and mosaicked of the three CCD images of the PAN camera of the IRS-1C satellite can be used with existing line scanner modelling systems to achieve accuracy between 0.5 and 1 pixel over terrain of moderate relief. As the use of the raw three CCD array images may improve the geometric and radiometric aspects of the imagery further research is required to rigorously model the three CCD geometry of the PAN camera of the IRS-1C. This is being realized by the mapping community (i.e., Cheng and Toutin, 1998; Jacobsen, 1998; Toutin et al., 1998). The 6-bit quantization of the image data results in low contrast imagery, thus making detection and identification of features more difficult. When contextual information, such as superimposed "old" vector data, is available, the situation is improving and the imagery has the potential to be used for updating certain features in new suburban developments and in non-urban areas. Therefore, from both the geometric and content aspects the IRS-1C imagery has the potential to support the national 1:50000 topographic map scale. The season of the image acquisition is a significant factor in the features identification.

As aerotriangulation points from existing aerial photographs may be difficult to identify and transfer to the satellite imagery, and as control information from medium and small scale maps will not meet the accuracy requirements, digital orthophotos and orthophoto chips are expected to become one of the main sources for control requirements for the high resolution imagery.

From the economic point of view the cost per square km for the IRS-1C imagery is $0.71CDN and for the1:50000 aerial photography (including scanning at 1000ppi) is $2CDN. On the information side, the cost per pixel for the IRS-1C PAN imagery is 5.6 times more expensive that the cost of the pixel of the aerial digitized photograph.

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